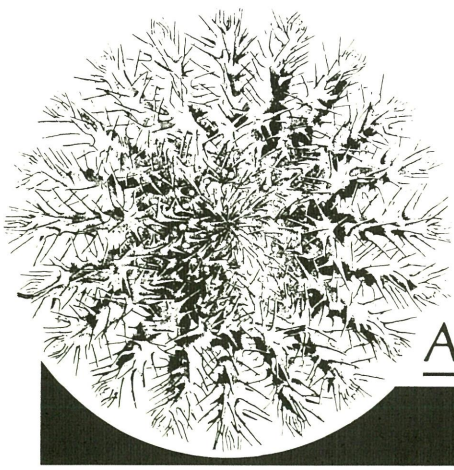
Report on the progress of COTSREC Ecological Research: July 1989 - February 1991

P.J. Moran and D.B. Johnson



Australian Institute of Marine Science

The Crown-of-thorns Study

Crown-of-thorns Study Report 12

May 1991

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PREFACE

Parts of this document were prepared using information supplied by research staff within the Crown-of-thorns Study. Their assistance is greatly appreciated.

The support of the Australian Institute of Marine Science is gratefully acknowledged as is the dedication of Christine Cansfield-Smith who produced and edited this document.

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INTRODUCTION

This document provides an overview of research conducted within the Crown-of-thorns Study at the Australian Institute of Marine Science(AIMS) since the end of June 1989. Funds for this research were provided by the Great Barrier Reef Marine Park Authority (GBRMPA) as recommended by the Crown of Thorns Starfish Research Committee (COTSREC).

The research described in this document is covered by a formal Agreement which was established between GBRMPA and AIMS on 14 November 1989. This document arose after problems were experienced in relation to the ownership of information and the reporting of results. An independent review of the previous research program (under the auspices of the Crown of Thorns Starfish Advisory Review Committee) by Professor D. Anderson also drew attention to these issues. This review was undertaken during January 1989 at the request of the then Minister for the Arts, Sport the Environment, Tourism and Territories, Senator the Honourable Graham Richardson.

As a consequence of that review an Agreement was developed which covered such topics as: the responsibilities of each institution and relevant personnel; reporting procedures, schedule for the allocation of funds, ownership of capital equipment and research information, procedures for the disclosure of information, dealing with potential conflicts and the content of reports.

The Agreement was revised on 27 July 1990 to incorporate new or modified Tasks for the next fiscal year (i.e. 1990/91). In general, progress reports on the majority of research Tasks were provided to GBRMPA on 30 April 1990 and 30 October 1990 as stipulated in the two Agreements.

While each Agreement contained a schedule for the payment of funds (quarterly in advance) a lengthy delay in funding was experienced at the beginning of the 1989/90 fiscal year. As some of the Tasks were on-going funds were required to ensure the continuous employment of staff. Accordingly, GBRMPA provided $75,000 (from carry forward funds) to cover the costs incurred during this hiatus in funding.

Unfortunately this led to delays in the commencement of certain Tasks as there were insufficient funds to employ new staff. Nonetheless, selection procedures were conducted during this period so that staff could be appointed once additional funds were received.

The first major payment of funds was made in early December 1989. Within two weeks an additional two staff had been appointed to undertake research into the survival of juvenile crown-of-thorns starfish. One of these, Dr J. Keesing, was appointed as a Postdoctoral Fellow to lead this research. Another Postdoctoral Fellow, Dr R. Babcock, was appointed in early January to lead investigations into the reproduction of crown-of-thorns starfish. Research into this area had been recommended previously by a sub-Committee comprising Dr L. Zann, Dr P. Moran, A/Prof. J. Lucas and Dr J. Lawrence (corresponding member).

STRUCTURE OF STUDY

At present the Crown-of-thorns Study comprises 9 separate Tasks. Each has a unique number that corresponds to that given in the main body of the Agreements. Eight of the Tasks involve research while the remaining Task provides administrative support to the others. Administrative aspects of the Study, including budgets, are discussed in the next section.

The complete titles for the 9 research Tasks are as follows:

Task 6.1.1: Broadscale surveys of the crown-of-thorns starfish and its effects on corals along the Great Barrier Reef.

Task 6.1.2: Field surveys of juvenile crown-of-thorns starfish.

Task 6.1.3: Analysis of coral colonies, populations and communities: interpretation of outbreak history and projection of recovery.

Task 6.1.4: Assessment of the utility of mitochondrial DNA as a genetic marker in crown-of-thorns starfish (*A. planci*).

Task 6.1.5: The role of predation in factors influencing the survival of small juvenile *Acanthaster planci* cultured in the laboratory.

Task 6.1.6: Reproductive biology of the crown-of-thorns starfish.

Task 6.1.7: Project support and administration.

Task 6.2.1: Investigation of the trophodynamic implications of outbreaks of the crown-of-thorns starfish.

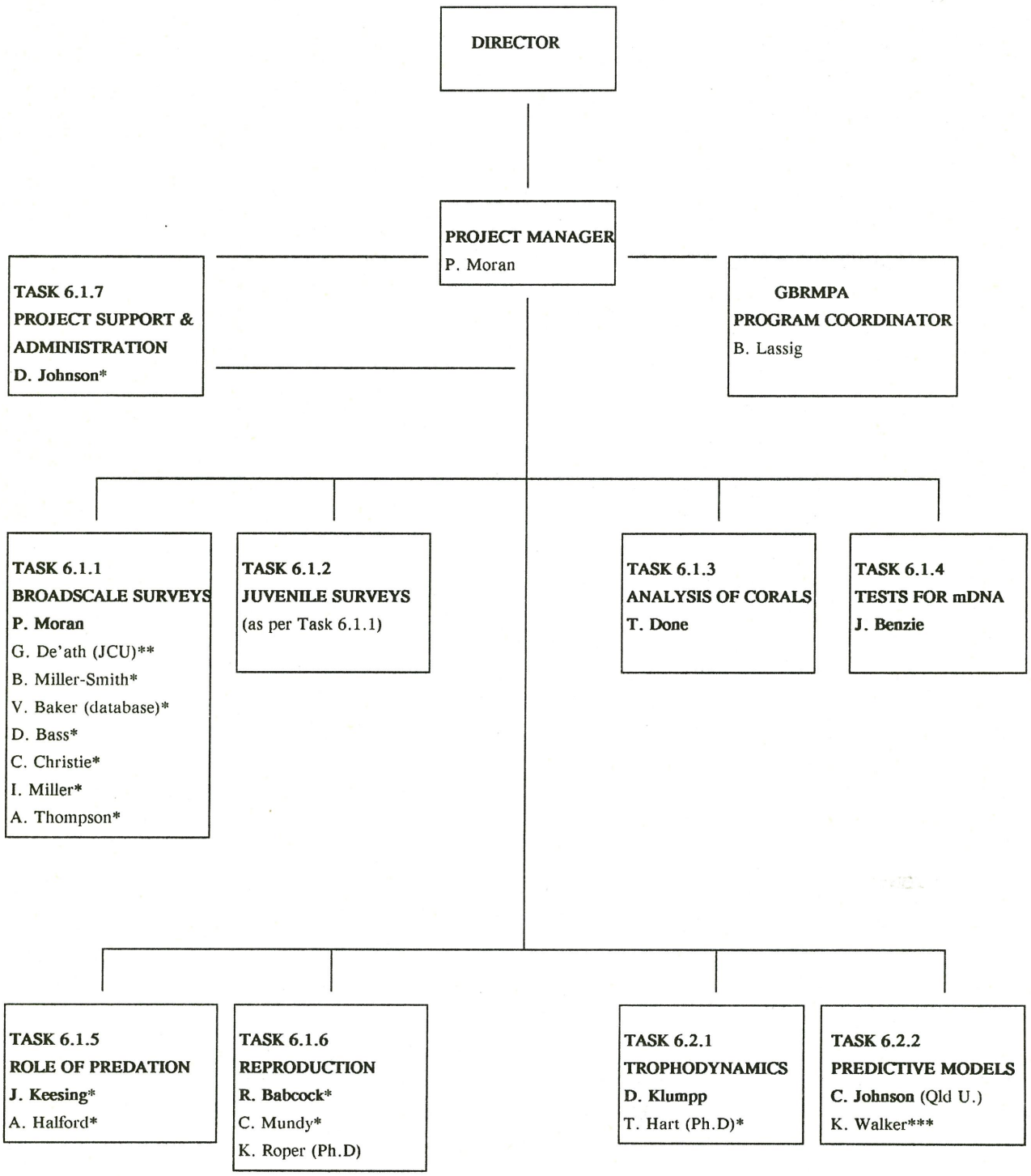
Task 6.2.2: Impact of crown-of-thorns starfish on interactions among space occupants of coral reefs: predictive models of coral reef community structure.

The overall structure of the Study is presented in Figure 1 in the form of an organisational flow chart. Each of the Tasks within the Study has a Leader who is responsible for controlling the resources of that Task as well as ensuring that the research objectives are completed as efficiently and effectively as possible. The Task Leaders report to the Project Manager who is responsible for coordinating and managing the entire Study (including all research, personnel and resources). The Project Manager in turn reports to the Director of AIMS and liaises with the Program Coordinator at GBRMPA.

The Crown-of-thorns Study forms a discrete project within the Reef Studies program at the Institute.

In all, there are presently 13 staff employed in the Study: two are Postdoctoral Fellows (Tasks 6.1.5 and 6.1.6), nine are Professional Officers (Task 6.1.1 has 5 survey team members and a database manager; Tasks 6.1.5, 6.1.6 and 6.2.2 have one each). There are also two Ph.D students in the Study (Tasks 6.1.6 and 6.2.1). It should be noted that the Professional Officers connected with Tasks 6.1.6 and 6.2.2 were appointed on contract, for 9 and 6 months, respectively. All other staff were appointed according to the terms and conditions of the Institute and continued employment was subject to renewed funding.

*Figure 1. An organisational flow chart for the Crown-of-thorns Study. Names of Task Leaders given in bold. *Indicates staff appointed with funds from COTSREC. ** Mr De'ath provides statistical advice under contract to AIMS. ***Ms Walker is engaged as a scientific contractor. All other personnel funded through AIMS expenditure.*



ADMINISTRATION AND FINANCE

A total of $1,033,685 has been allocated by GBRMPA for research at AIMS for the 1989/90 ($459,000) and 1990/91 ($574,685) fiscal years (Table 1). During 1989/90 GBRMPA also allocated, $16,000 for the PhD project being undertaken by Mr L. DeVantier (which is administered by AIMS) and another $5,000 to support research within Task 6.2.2 (from unspent funds). A further $5,000 was allocated to support Mr DeVantier's project during 1990/91.

In all, $25,075 was carried forward from previous fiscal years. Funds were allocated to the 9 projects as recommended by COTSREC and stipulated in the Agreement between the two institutions (see Table 1).

Over the last 18 months funds have been spent mainly in the following areas:

1. Approximately 60% was spent on salary-related items: this includes $407,762 for base salaries; $8,721 for diving allowances; $22,635 for compulsory superannuation (calculated as 3% of gross salaries) and Worker's Compensation (calculated as 3.84% of gross salaries); and $3,924 for recreation leave fare entitlements. Funding was insufficient to allow staff to join the Commonwealth Superannuation Scheme.

2. About $23,453 was spent on meeting the costs associated with travel for staff to undertake research (e.g. field research). Of this amount, $11,184 was used by Dr Keesing to undertake collaborative research in Japan.

3. A further $44,995 was spent on stores and consumables for all projects within the Study. A relatively small amount of capital equipment ($10,007) was purchased mostly to upgrade the seawater system used to hold starfish and culture larvae.

4. The Study puts a large drain on the resources of AIMS. To offset this, on-costs are paid (ca. 20% of base salary) to cover infrastructure costs, principally: power, water, electricity, photocopying, telephones, and support services (administration and accounting, personnel, library,

computing, stores, workshops, marine section, dive stores). To date, about $85,006 (11.5%) has been paid in the form of on-costs to the Institute.

5. A significant amount of funds ($18,785) was used in the maintenance and hire of vehicles to transport staff to and from the Institute. This is a requirement of all externally funded projects and is part of the terms and conditions of employment for all staff.

6. Other significant areas of expenditure to date include contract labour ($32,710), research grants ($30,500), external ship charter ($14,750) and publications ($9,432).

The Institute also puts considerable resources into the Study. Notional figures for each project are given in Table 1. The majority of this support comes in the form of: shiptime, computing, staff, and stores. Over the last 18 months the Institute provided 250 days of shiptime (39 cruises) for research Tasks within the Crown-of-thorns Study. Approximately 85% of this time was allocated on the RV Sirius. It should also be mentioned that the Institute has provided large amounts of specialised equipment (e.g. Remotely Operated Vehicle, computers, spectrophotometers, freeze dryers) without charge. As well, it has paid for the visits of several scientists from overseas (e.g. Dr J. Lawrence, University of South Florida) under its Visiting Investigators Program.

Table 1. ***Funds allocated to Tasks within the Crown-of-thorns Study during 1989/90 and 1990/91 fiscal periods. Figures for the notional support given by AIMS to each Task are also provided. They are derived from the original Task proposals. A dash (-) indicates where funds were not requested.***

Task No.	Funds allocated ($) 1989/90		1990/91		Total	
	GBRMPA	AIMS	GBRMPA	AIMS	GBRMPA	AIMS
6.1.1	203,123	72,000	220,221	80,000	423,344	152,000
6.1.2[a]	-	9,600	-	-	-	9,600
6.1.3	20,000	35,690	-	-	20,000	35,690
6.1.4	4,000[b]	4,051	-	4,216	4,000	8,267
6.1.5	67,271	10,500	93,639	19,500	160,910	30,000
6.1.6	40,417	-	105,727	19,500	146,144	19,500
6.1.7	130,764	39,871	155,098	51,717	301,862	91,588
6.2.1	-	-	13,500[c]	115,394	13,500	115,394
6.2.2	-	-	10,000[d]	-	10,000	-
TOTAL	465,575[e]	171,712	598,185[f]	290,327	1,079,760	462,039

a support for this project covered within Task 6.1.1
b funds carried forward into 1990/91 due to delays in research
c funds carried forward from previous fiscal period.
d $5,000 from previous fiscal period, (remainder provided by GBRMPA from unspent funds)
e total allocation by GBRMPA $459,000: $6,575 uncommitted funds from previous year
f total allocation by GBRMPA $574,685

PROGRESS OF RESEARCH

This section provides a brief summary of the progress made in each Task. More detailed information (e.g. research objectives, work completed) concerning these Tasks can be found in previous progress reports (April and October, 1990). The general status for each Task is given in Table 2.

Task 6.1.1

Title

Broadscale surveys of the crown-of-thorns starfish and its effects on corals along the Great Barrier Reef.

Background

Broadscale surveys of crown-of-thorns starfish and corals were initiated at the beginning of 1985 as part of a Commonwealth Community Employment Program. During that year 228 reefs were surveyed in an area from Whyborn Reef near Cape York to Lady Musgrave Island off Gladstone (Moran *et al.* 1988). This was the first time in the history of the GBR that it had been surveyed using the same technique over its entire geographic range within one year.

The results of the survey provided, for the first time, a general understanding of the extent of activity and effects of the crown-of-thorns starfish. In a bid to further improve the clarity of this picture the surveys were continued on an annual basis with funds supplied by the GBRMPA through the auspices of the Crown of Thorns Starfish Advisory Committee (COTSAC), the Crown of Thorns Starfish Advisory Review Committee (COTSARC) and more recently the Crown of Thorns Starfish Research Committee (COTSREC).

Objectives

This survey project has two main objectives:

1. To assess and summarise the broadscale distribution and effects of the crown-of-thorns starfish within the last 9-10 years.

2. To develop a scientific understanding of the broad spatial and temporal dynamics of the crown-of-thorns starfish and its hard coral prey.

Progress

The Task continues to progress as planned. A total of 168 reefs was surveyed along the GBR between June 1989 and May 1990. The results of these surveys were presented in a Technical Report by Baker *et al.* (1990). A synthesis of the results was produced shortly after as required under the Agreement established between GBRMPA and AIMS. This subsequently was produced as a Technical Report (Moran *et al.*, 1991).

A total of 102 reefs have been surveyed during this fiscal year. An additional 34 reefs remain to be surveyed in the Whitsunday and Pompey Sectors. The perimeters of most reefs surveyed during this fiscal year have already been digitised and work on the Technical Report is underway. A paper which describes the pattern of movement of the outbreaks over the last 10 years is in preparation.

Apart from surveying reefs staff have also been involved in several other activities:

1. Manta video: this was trialled once and a number of technical and logistic problems were encountered (e.g. the viewing width has to be 2m or less in order to gain sufficient resolution). Consequently, the technique is not considered to be a viable alternative to manta towing at the present time.

2. Bias with respect to coral cover: considerable time (ca. 80 person days) was spent in assisting Ms L. Fernandes in the field. This work was completed towards the end of 1990.

3. ROV: unfortunately the ROV purchased by AIMS has experienced several technical problems which have largely prevented survey team members from using it. These have been rectified recently and a field trial is planned for the middle of the year.

The 5 survey team members each spent an average of 100 days at sea during 1990.

References

Baker, V.J., Bass, D.K., Christie, C.A., Miller, I.R., Miller-Smith, B.A., Thompson, A.A. and Mundy, C.N. (1990). Broadscale surveys of crown-of-thorns starfish on the Great Barrier Reef 1989 to 1990. The Crown-of-thorns Study. Australian Institute of Marine Science: Townsville. 204p.

Moran, P.J., Bradbury, R.H. and Reichelt, R.E. (1988). Distribution of recent outbreaks of the crown-of-thorns starfish (*Acanthaster planci*) along the Great Barrier Reef: 1985-1986. Coral Reefs 7: 125-137.

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Task 6.1.2

Title

Field surveys of juvenile crown-of-thorns starfish.

Background

Large populations of juvenile crown-of-thorns starfish have been recorded infrequently in the Indo-Pacific region. The most intensively studied has been that reported by Zann *et al.* (1987, 1990) on the reefs near Fiji. Similar, high density populations have not been reported up to the present time on the Great Barrier Reef. This has prevented the initiation of several important studies (e.g. effects of fish predation on survivorship of juvenile starfish) of the early life history of the starfish. A series of intensive underwater surveys were planned therefore, to try and locate suitable populations so that these studies could proceed.

Objective

The main objective of this Task is to locate an extensive, high density population of juvenile crown-of-thorns starfish on the Great Barrier Reef.

Progress

A total of 51 sites were surveyed on 14 reefs during October and November 1989. The surveys were undertaken mainly on reefs immmediately south of the main concentration of outbreaks (i.e. between Cape Upstart and the Whitsunday Islands). Several reefs (e.g. Davies, Bowden) with large populations of adult starfish were also included in the surveys. In all, only 14 juvenile starfish were found during the surveys at a notional cost of about $1,200 each. Small feeding scars (white coral) were found to

be unreliable indicators of the presence of these starfish (see Research Findings). A detailed account of the results of the surveys is given in a Technical Report which will be published in May.

A further series of surveys was planned for the following year (December 1990) however, they did not go ahead as the shiptime was used to support higher priority research (see Task 6.1.6). These changes were undertaken with the approval of GBRMPA.

References

Zann, L., Brodie, J., Berryman, C. and Naqasima, M. (1987). Recruitment, ecology, growth and behaviour of juvenile *Acanthaster planci* (L.)(Echinodermata: Asteroidea). Bull. Mar. Sci. 41: 561-575.

Zann, L., Brodie, J. and Vuki, V. (1990). History and dynamics of the crown-of-thorns starfish *Acanthaster planci* (L.) in the Suva area, Fiji. Coral Reefs 9: 135-144.

Task 6.1.3

Title

Analysis of coral colonies, populations and communities: interpretation of outbreak history and projection of recovery.

Background

This Task attempts to understand the significance of recent crown-of-thorns outbreaks in relation to the dynamics of coral communities. Analysis of corals as individual colonies, as populations, and as communities can help develop that understanding.

The massive corals provide a focus for this study as the replacement time for individuals may be very long (Cameron and Endean, 1985). Previously, a simple model was used to assess recovery times on a case by case basis (Done, 1987, 1988).

It was proposed to conduct additional field work at sites surveyed as the basis for previous projections of population and community recovery (Done, 1987,1988; Done *et al.*, 1988). Resurveys will provide estimates of recruitment and survivorship at these specific sites, thereby improving the utility of these model projections.

Objectives

The main objectives of this project are to:

1. Understand the significance of recent crown-of-thorns starfish outbreaks in relation to the population dynamics of coral communities, for the time period from the present up to 200 years into the future.

2. Resurvey sites to provide estimates of recruitment and survivorship of massive coral colonies, thereby improving the utility of previous model projections.

Progress

Originally this Task was due to be completed by October 1990. However, due to other commitments the Task Leader was unable to prepare the draft final report. Submission of this document has since been deferred until June 1991 with the approval of the GBRMPA.

All field work connected with this Task has been completed and the data have been checked and stored. An additional cruise was needed to complete the field work due to the effects of cyclone Ivor. The data are presently being analysed and the report will be completed within the stated deadline.

References

Cameron, A.M. and Endean, R. (1985). Do long-lived species structure coral reef ecosystems? Proc. 5th Int. Coral Reef Congr. 6: 211-216.

Done, T.J. (1987). Simulation of the effects of *Acanthaster planci* on the population structure of massive corals in the genus Porites: evidence of population resilience? Coral Reefs 6: 75-90.

Done, T.J. (1988). Simulation of the recovery of pre-disturbance size structure in populations of Porites spp. damaged by the crown-of-thorns starfish *Acanthaster planci*. Mar. Biol. 100: 51-61.

Done, T.J., Osborne, K. and Navin, K.F. (1988). Recovery of corals post-*Acanthaster*: progress and prospects. Proc. 6th Int. Coral Reef Symp. 2: 137-143.

Task 6.1.4

Title

Assessment of the utility of mitochondrial DNA as a genetic marker in crown-of-thorns starfish (*A. planci).*

Background

Previous research (Benzie and Stoddart 1988; Benzie 1990a,b; Benzie and Stoddart submitted a,b) has indicated that highly variable genetic markers are required to undertake sensitive analyses of the genetic structure of crown-of-thorns starfish populations. Mitochondrial DNA (mDNA) offers the potential for reliably detecting genetic variation in population structures where only a small number of animals can be collected. This is for several reasons: firstly, mDNA has potentially greater levels of genetic variation, secondly, mDNA is inherited from the mother, and thirdly, selection is less likely to act on mDNA variants. This is particularly useful for studying non-outbreak populations of crown-of-thorns starfish which often have few individuals.

Objectives

The primary objective of this Task is to establish methodologies for the extraction of mitochondrial DNA from crown-of-thorns starfish and to assess its utility as a genetic marker.

Progress

This Task originally was to be completed in June 1990 however, due to delays in the construction and renovation of Institute laboratories the completion date has been put back a year (i.e. 30 June 1991).

Processing of ripe ovary and pyloric caeca was undertaken towards the end of 1990. To date, only very small amounts of mDNA have been extracted, which are clearly inadequate for population genetic work. Attempts are being made to improve these yields by altering the extraction conditions. This is being done in two ways: firstly, by modifying the concentration of EDTA and secondly, by using a higher salt extraction step. The latter is viewed to be important since previous experiments used relatively low salt concentrations in precipitation steps and this may have affected yield. This series of experiments should be completed by May 1991.

Another major problem is that the mDNA is in a highly degraded state when it is collected. This is clearly a result of strong nuclease activity. Total DNA is still degraded even under stringent conditions, although this is less than in standard procedures.

If appropriate procedures can be developed for extracting mDNA, then several starfish populations will be tested during the next spawning season when gonad tissue will be available. The expected date for completion of tests on extraction procedures is May 1991.

References

Benzie, J.A.H. (1990a). Techniques for the electrophoresis of crown-of-thorns starfish *(Acanthaster planci)* enzymes. The Crown-of-thorns Study. Australian Institute of Marine Science: Townsville, 27p.

Benzie, J.A.H. (1990b). Genetic relationships of crown-of-thorns starfish. In: Done, T.J. and Navin, K.F. eds. Vanuatu Marine Resources. Australian Institute of Marine Science: Townsville, 114-117.

Benzie, J.A.H. and Stoddart, J.A. (1988). Genetic approaches to ecological problems: crown-of-thorns starfish outbreaks. Proc. 6th Int. Coral Reef Symp. 2: 119-124.

Benzie, J.A.H. and Stoddart, J.A. (Submitted a). The population genetics of crown-of-thorns starfish *(Acanthaster planci)* outbreaks on the Great Barrier Reef. Marine Biology.

Benzie, J.A.H. and Stoddart, J.A. (Submitted b). The genetic structure of crown-of-thorns starfish *(Acanthaster planci)* in Australia. Marine Biology.

Task 6.1.5

Title

The role of predation in factors influencing the survival of small juvenile *Acanthaster planci* cultured in the laboratory.

Background

Whilst the cause of temporal fluctuations in the abundance of *A. planci* is still not known, recent studies suggest that adult populations are limited by food (coral) availability, but larvae are not (Olson, 1987). Thus larval survivorship probably is not enhanced by temporal variability in phytoplankton abundance. It is most likely then, that variation in A. planci population size is due to variability in recruitment levels and/or the level of survival of newly recruited animals. While much of the research over the last few years has focused on recruitment and hydrodynamics, very little attention has been given to investigating the survival of starfish after recruitment. The justification for focusing on this latter aspect comes from recent modelling and ecological studies which have suggested that survival rates of post-metamorphic echinoderms may be more important than the levels of larval recruitment (McCallum, 1988; Rowley, 1989).

Objectives

The main objectives of this Task are:

1. To measure the survival of small juvenile *A. planci* in the field.

2. To enable predictions about the recruitment levels required to precipitate outbreaks.

3. To identify the factors (particularly the role of predators) which influence the survival rate of juvenile starfish.

In order to achieve these objectives it is necessary to conduct a series of experimental procedures using large numbers of small starfish. Due to the difficulties of locating large numbers of juvenile *A. planci* in the field the first phase of this project involves raising experimental animals in the laboratory.

Progress

This Task began towards the end of 1989. Considerable time has been spent in devising and refining the necessary procedures and facilities for rearing large numbers of larvae and undertaking experimental manipulations in the field. Overall, progress in this Task has been good despite the many technical and logistic problems. Extensive field surveys of benthic fauna have been undertaken and over half of the samples have

been sieved and sorted. Several different laboratory experiments also have been conducted which have investigated the survival of juvenile starfish and their growth on different substrata.

More recently, two batches of larvae were successfully reared to settlement. There are now about 10,000 small starfish being kept in the system – a world first. Two main lessons were learnt from this exercise: firstly, rearing was productive but labour intensive and secondly, the success of the operation could be further enhanced if the factors that were critical in the rearing process could be identified.

Two successful deployments of small starfish using caging techniques have been made in the last few weeks. These have produced a number of preliminary results (see Research Findings). Recent wet weather has reduced the salinity (ca. 19 ppt, normally 35 ppt) in aquaria thereby hampering laboratory experiments.

References

McCallum, H.I. (1988). Predator regulation of *Acanthaster planci*. J. Theor. Biol. 127: 207-220.

Olson, R.R. (1987). *In situ* culturing as a test of the larval starvation hypothesis for the crown-of-thorns starfish, *Acanthaster planci*. Limnol. Oceanogr. 32: 895-904.

Rowley, R.J. (1989). Settlement and recruitment of sea urchins (*Strongylocentrotus* spp.) in a sea-urchin barren ground and a kelp bed: are populations regulated by settlement or post-settlement processes? Mar. Biol. 100: 485-494.

Task 6.1.6

Title

Reproductive biology of the crown-of-thorns starfish.

Background

Successful reproduction is the first critical step in the life cycle of the crown-of-thorns starfish. Given the enormous reproductive potential of the starfish (Kettle and

Lucas, 1987) relatively small changes in reproductive success for individuals may lead to large changes in population size.

Despite its obvious importance there is a surprising lack of knowledge concerning many aspects of the reproduction of the crown-of-thorns starfish. Variation in the degree of reproductive success has been implicated in attempts to explain outbreaks of the starfish (Dana, 1970; Moore, 1978). Thus the reproductive biology of the crown-of-thorns starfish represents a major gap in our understanding of the processes which may be responsible for large fluctuations in the populations of this animal.

Objectives

The main objectives of this Task are to:

1. Determine the timing and extent of spawning of crown-of-thorns starfish.

2. Investigate the factors affecting reproduction.

3. Determine the effects of adult density on fertilisation success.

Progress

This Task began in January 1990 with the appointment of Dr R. Babcock. He spent the first 3 months developing a detailed research plan which was submitted for external peer review. Considerable time then was spent in planning the research that was to be undertaken during the 1990/91 spawning season. Originally these plans involved the support of the Navy (e.g. manpower and boats). Unfortunately this support did not eventuate thereby necessitating significant alteration of ship usage in the Study. Sufficient seatime was obtained on Institute ships by using shiptime dedicated for surveys of juvenile starfish (Task 6.1.2). These changes were agreed to by GBRMPA.

While the withdrawal of Navy support limited the scope of what could be done in the field, the proposed research proved to be very successful. A mass spawning of about 100 starfish was recorded allowing a variety of important factors (e.g. fertilisation success versus distance, effects of density, variability in timing of spawning, starfish behaviour) to be investigated (see Research Findings). This is the first time that these factors have been recorded under natural conditions.

Laboratory investigations of spawning pheromones have produced inconclusive results, as no clear pattern in sperm chemotaxis could be identified using normal techniques. Preliminary studies using oxygen electrodes have indicated that it may still be possible to demonstrate this effect. These experiments are planned for the end of 1991. The recent decline in salinity in aquaria has forced the cancellation of several experiments on aggregation of starfish.

Research into the use of monoclonal antibodies as potential markers for larvae has progressed steadily. At present, plankton samples are being tested for the presence of larvae of crown-of-thorns starfish. Deployment of settling tubes was partially successful. A number of tubes were damaged or lost as a result of the effects of cyclone Joy. Most contained large quantities of sediment which will considerably extend the time required for processing.

References

Dana, T.F. (1970). *Acanthaster*: a rarity in the past? Science 169: 894.

Kettle, B.T. and Lucas, J.S. (1987). Biometric relationships between organ indices, fecundity, oxygen consumption and body size in *Acanthaster planci* (L.) (Echinodermata: Asteroidea). Bull. Mar. Sci. 41: 541-551.

Moore, R.J. (1978). Is *Acanthaster planci* an r-strategist? Nature 271: 56-57.

Task 6.2.1

Title

Investigation of the trophodynamic implications of outbreaks of the crown-of-thorns starfish.

Background

Outbreaks of crown-of-thorns starfish change coral reefs from a "balanced" coral/algal community to one dominated by turf algae (>90% cover). Preliminary research has indicated that this substantial change in reef state may lead to a 4-fold increase in the net production of the benthic food resources available to grazing organisms.

While long term observations suggest that the biomass of herbivorous fishes does not change in response to this increase in food (Williams, 1987), very little else is known about the potential effects of such changes. Perhaps grazers increase their feeding rate or alternatively the additional biomass may be underutilised and channelled instead into detrital pathways. Investigation of the trophodynamic implications of outbreaks will provide fundamental information on the utilization and conservation of energy and nutrients on coral reefs.

Objectives

This Task has two main objectives:

1. To compare algal production, herbivory and detrital processes on "healthy" reefs and those affected by outbreaks of crown-of-thorns starfish.

2. To assess the trophic response of reefs to outbreaks of crown-of-thorns starfish, particularly in relation to the extensive coral mortality and resulting blooms in benthic algae.

Progress

This Task began in December 1990 with the appointment of a postgraduate student (Mr T. Hart) to undertake the research. To date, progress has been rapid. A preliminary research plan has been devised and will be submitted in final form for the consideration of COTSREC. Fieldwork has already commenced and two cruises have been successfully completed. Cages to be used for experimental manipulations in the field are presently being constructed at AIMS. They are expected to be deployed in April.

References

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Task 6.2.2

Title

Impact of crown-of-thorns starfish on interactions among space occupants of coral reefs: predictive models of coral reef community structure.

Background

Funds for this project were given to employ a technical assistant to process field samples collected as part of an AIMS postdoctoral program of research by Dr C. Johnson (now at the University of Queensland). The field component of this project has been completed and the samples are in frozen storage at AIMS awaiting processing. A detailed description of the project including research objectives were given in the original research proposal submitted to COTSREC in May 1990.

Objectives

The main objective of the present Task is to examine substrata from two field experiments (reciprocal transfers and effect of established organisms on recovery) designed to investigate differences in the recruitment processes of corals, crustose coralline algae (CCA) and turf algae among "healthy" reefs and those affected by crown-of-thorns starfish.

Progress

This Task began in June 1990. The immediate objective was to complete the analysis of samples collected as part of experiment 1 (reciprocal transfers). Ms Kaye Walker was appointed on a short-term contract in mid-June to undertake the analyses. Unfortunately, the funds were insufficient to enable Ms Walker to complete them in the time available. Consequently, a small amount of additional funds (ca. $3,000) were used to extend the contract into mid-December, thereby allowing her time to complete the work. It is likely that she will continue this work throughout much of 1991 with funds obtained from the University of Queensland. This should be sufficient to complete all the analyses.

Table 2. ***Summary of the general status of research Tasks. Changes to completion dates and/or objectives are also shown.***

Task	Status	Start	Finish
6.1.1	102 reefs surveyed (90/91), report underway	Dec. 1985	June 1992
6.1.2	1990 surveys cancelled, report underway	Dec. 1989	June 1992
6.1.3	Fieldwork complete, analyses underway	June 1989	June 1991[a]
6.1.4	Samples processed, technical problems	Dec. 1989	June 1991[b]
6.1.5	Culturing successful, fieldwork underway	Dec. 1989	June 1992
6.1.6	Spawning observed, samples being processed	Jan. 1989	June 1992
6.2.1	Student appointed, fieldwork underway	Dec. 1990	Dec. 1993
6.2.2	Samples (stage 1) processed, funding supplied	Jun. 1990	Dec. 1991

a initial date for completion 30 October 1990
b initial date for completion 30 June 1990
c funds supplied by University of Queensland

RESEARCH FINDINGS

The following results have been obtained from the 8 research Tasks supported by COTSREC funds since June 1989. They are given in point form and grouped within several general headings.

As many of these findings are preliminary in nature they should not be cited in the scientific literature without reference to formally published papers.

1. Distribution and abundance of crown-of-thorns starfish.

(a) About a third (31.5%) of all reefs surveyed since 1982 have experienced outbreaks of crown-of-thorns starfish in the last 10 years. The estimated percentage of reefs which have experienced outbreaks over the entire GBR is 18% ± 4%.

(b) The number of outbreaking populations on the GBR is declining. The proportion of reefs with outbreaks (at the time of survey) rose from 7% in 1985/86 to 16% in 1988/89 and then dropped to around 4% during 1989/90.

(c) The starfish has mainly affected reefs between Lizard Island and Townsville over the last 10 years.

(d) The proportion of reefs with outbreaks in the Townsville region has steadily declined over the last few years (75% in 1985/86 to 13% in 1989/90). In contrast, the proportion of outbreaking populations in the region immediately to the south (Cape Upstart) has increased from 5% in 1985/86 to 37% in 1989/90. The data provide the first direct evidence of the southward drift hypothesis put forward in the mid-1970s.

(e) Recent analyses of the database (incorporating historical surveys and user reports) indicate:
– That the second series of recorded outbreaks on the GBR began in an area of reefs between Cairns and Cooktown during 1979 and 1980.

– After that time the outbreaks moved to the south of Cairns (at a rate of approximately 0.67 degrees/year) and to the north of Cooktown (at a rate of about 0.23 degrees/year).

– The direction of both the southern and northern drifts followed the line of mid-shelf reefs. The pattern of movement of the southerly drift is more dispersed either side of the drift path.

– The southerly and northerly drifts have now slowed to about 0.24 and 0.04 degrees /year, respectively.

(f) A total of 14 juvenile crown-of-thorns starfish, ranging in size from 5 to 15 cm in diameter, were observed during surveys carried out on 14 reefs between Townsville and Shute Harbour. Small feeding scars were found to be unreliable indicators of the presence of these small starfish. About 30% of all scars were directly attributed to the activity of the gastropod *Drupella.*

2. Survival of juvenile crown-of-thorns starfish.

(a) Mass culturing techniques produced approximately 10,000 juvenile starfish during the 1990/91 spawning season. This represents an order of magnitude increase over the previous year. In general, it was found that only a small proportion of larvae ever attained the competency to settle. This was despite the fact that there was relatively high survivorship during larval development.

(b) The rate of survival of newly settled starfish was found to increase with age in the laboratory. Mean survival rates for starfish aged 14 days, 50 days and 420 days (after settlement) over a period of 100 days was 10%, 48% and 84%, respectively. Subsequent survival to 220 days was high for all ages. These results suggest that mortality of juvenile starfish is probably high initially after settlement but that it stablises to a lower level.

(c) Losses of small starfish (1-2 mm diameter) were significant when exposed to benthic treatments containing crabs. No direct predation however, was observed.

(d) Natural coral rubble habitats are likely to contain a range of hazards which result in the death of significant numbers of small starfish. Recovery of these starfish after 6 days in field cages containing natural coral rubble (and attached epibiota) was 62% compared with 92% in control cages.

(e) The growth rate of juvenile crown-of-thorns starfish varied enormously over a four month period. Food type accounts for this large difference. Those that were fed *Seriatopora hystrix, Pocillopora damicornis, Stylophora pistillata* and *Acropora formosa* achieved the most superior growth rates (6-8 mm/month), while those fed *Goniastrea retiformis, Porites lichen* and *Porites lutea* grew slowest (0.2-0.7 mm/month).

3. Reproduction of crown-of-thorns starfish.

(a) About 100 crown-of-thorns starfish were observed spawning in synchrony at approximately 9.30 pm on Friday 7 December 1990 at Davies Reef. Most of the starfish were aggregated, occurring in small clusters of 2-3 individuals over a distance of about 100m. Prior to spawning the starfish sought prominent locations, climbing onto coral heads and rocky outcrops. Most adopted a bell-shaped posture when releasing gametes.

(b) Another 3 starfish (all males) were observed to spawn approximately 10 days after this event.

(c) The following results were obtained in relation to Gonad Index (i.e. ratio of gonad weight to body weight)

– It increased slowly (to about 10%) until a few weeks before the mass spawning event.

– It then increased rapidly reaching a maximum of about 20%.

– It was larger in females than males.

– It had declined by about 50% after the mass spawning event.

– A further increase and decline was recorded, suggesting that another mass spawning event may have taken place during January. None was observed, however.

(d) Fertilisation success was high (80%-90%) between individuals located within a few metres of each other. This figure declined to about 60% at 10m, 40% at 16m, 30% at 30m, and 20% at 60m.

(e) Extracts of gonads were found to induce spawning in several individuals of both sexes.

4. Coral mortality and recovery.

(a) Surveys within the Cairns region have recorded noticeable coral recovery on some reefs. At the present time however, this is still patchy. Widespread damage due to cyclones has been recorded on a number of reefs in the Far Northern Section of the GBR.

(b) Almost 20% of reefs with outbreaks (at the time of survey) were considered to be seriously affected (i.e. reefs with an average dead coral cover of greater than 30%).

(c) Outbreaks of crown-of-thorns starfish produce an estimated 11% increase in the cover of dead coral on reefs. This represents over a threefold increase in the amount of dead coral.

(d) Recruitment of corals was greater in the presence of turf algae, inside fish territories, rather than outside the territories where grazing pressure is high. At present it has not been determined whether the higher levels of coral recruitment are due to the presence of turf algae, the resident fish or a combination of both.

(e) Growth of turf algae inhibits the spread of crustose coralline algae. The latter suffers from high mortality when transferred into fish territories.

THE FUTURE

Initial delays in funding have meant that certain Tasks (notably 6.1.5 and 6.1.6) were not able to make full use of the 1989/90 spawning season. Indeed, the season had almost passed by the time these Tasks were fully operational. This has retarded their progress by almost a year since it was hoped that they could make use of that spawning season to undertake preliminary experiments. Many of these were subsequently conducted in the 1990/91 season. Given this and the fact that research is expected to be completed by June 1992 (which allows for only one more spawning period) it is suggested that funding be given to extend these projects so that they are able to make use of the spawning season in the 1992/93 fiscal year. Such extentions would have substantial benefits in terms of results produced and in the light of funds expended.

On a more pragamatic level it should be pointed out that a commitment exists to fund Ph.D students within the Study for a maximum period of 3 years. In some cases (e.g. Task 6.2.1) the commitment extends beyond the duration of the present Study.

Broadscale surveys of the GBR have been underway for almost 6 years. Over that time there has been an appreciable increase in our understanding of the extent of the crown-of-thorns problem. Recent results (see Research Findings) demonstrate how important it is to undertake regular and standardised monitoring of large ecosystems both for improved scientific understanding and wise management.

It is just as important to monitor crown-of-thorns starfish when they are not present as well as when they are present. Consequently the present broadscale surveys need to continue even though the activity of the starfish is declining. Consideration therefore, needs to be given to perhaps broadening the basis for monitoring and building it within a framework that encapsulates the general requirements of GBRMPA and AIMS.

A large number of projects have investigated issues pertaining to the *Acanthaster* phenomenon. Some have addressed key processes (e.g. larval development and survivorship, predation and reproduction), while others have investigated important, but more peripheral, issues (e.g. potential of remote sensing, bias in survey techniques).

Two other areas which perhaps should be investigated in the future and which have received scant attention in the past are:

1. Effects of nutrients and terrestrial runoff on larval survivorship of crown-of-thorns starfish.

2. Effects of outbreaks on calcification and reef growth.

Both address important issues: the first attempts to investigate the link between man and outbreaks, while the second examines the role played by outbreaks in the development and evolution of the GBR ecosystem. Understanding of the latter may well be important in the light of the Green House Effect.

The types of research that are supported in the future are likely to be determined not only by their relevance to understanding the *Acanthaster* phenomenon but also the cost of the work (in terms of the information gained). In relation to the latter, as more research is done fewer important gains in knowledge are expected in certain areas (e.g. recruitment). That is the cost expended per unit of information gained will rise. It is expected that this will be exacerbated by increasing costs associated with finding suitable populations of starfish to work on. Serious consideration should be given to these issues in future years to ensure that best possible use is made of any research funds that are available.

In view of the issues raised above some thought also should be given to setting aside funds in the event that a further series of outbreaks of crown-of-thorns starfish occurs on the GBR. This would ensure that a research program could be quickly developed thereby making maximum possible use of the event.

PUBLICATIONS

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